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U.S. PATENT APPLICATION

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Invention: LIQUID CRYSTAL DISPLAY DEVICE

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SPECIFICATION

LIQUID CRYSTAL DISPLAY DEVICE

FIELD OF THE INVENTION

The present invention relates to a liquid crystal display device (LCD) including a transmission/reflection combination type liquid crystal display panel. This type of LCD is used in, for example, a cellular phone, a PDA (personal digital assistance), on-vehicle equipment (such as a navigation system) and amusement equipment (such as a game machine).

DESCRIPTION OF THE RELATED ART

Recently, LCDs are widely used, owing to their features of having a small thickness and consuming low power, in OA appliances such as a word processor and a personal computer, portable information apparatuses such as a portable electronic scheduler, and a monitor for a camera-incorporated VTR.

The LCDs are roughly classified into two categories, that is, a reflection type and a transmission type. Specifically, since an LCD is not a selfluminous display device such as a CRT (Braun tube) or an EL (electroluminescence), a display is produced by using light emitted from an illuminator (that is, a so-called backlight) disposed behind a liquid crystal display panel in the transmission type and a display is produced by using ambient light in the reflection type.

The advantages and the disadvantages of the respective types are as follows: A transmission type LCD is advantageously so less affected by the ambient brightness that a bright display with a high contrast ratio can be produced, but disadvantageously consumes large power due to its backlight (which consumes approximately 50% or more of the whole power consumption). Furthermore, its visibility is disadvantageously lowered in a very

bright atmosphere (such as the outdoors in fine weather), or when the brightness of the backlight is increased for keeping the visibility, the power consumption is further increased. On the other hand, a reflection type LCD is advantageous in its very small power consumption because it does not need a backlight, but its display brightness and contrast ratio are disadvantageously largely affected by the use condition such as the ambient brightness. In particular, its visibility is extremely lowered in a dark atmosphere.

Accordingly, in order to attain the advantages of both of these types while eliminating the disadvantages thereof, an LCD that has a function to produce displays in both reflection and transmission display modes has been proposed.

Each pixel of such a transmission/reflection combination type LCD includes, as schematically shown in a cross-sectional view of FIG. **6**, a reflection pixel electrode part **101** for reflecting the ambient light entering in the downward direction in the drawing and a transmission pixel electrode part **102** for transmitting light of a backlight entering in the upward direction in the drawing. Therefore, a display can be produced in the both display modes, or alternatively, a display can be produced in either mode switched between the transmission display mode and the reflection display mode in accordance with the use condition (namely, the ambient brightness). Accordingly, a transmission/reflection combination type LCD has the advantage of the reflection type LCD, that is, the small power consumption, as well as the advantages of the transmission type LCD, that is, being less affected by the ambient brightness and being capable of producing a bright display with a high contrast ratio. In addition, the disadvantage of the transmission type LCD, that is, lowering of the visibility in a very bright atmosphere, is suppressed.

In the above-described transmission/reflection combination type LCD, with respect to the thickness of a liquid crystal layer **151** interposed between a counter electrode substrate **103** and a pixel electrode substrate **104**, the thickness **Rd** in a reflection region **R**

should be approximately a half as large as the thickness **Td** in a transmission region **T** ($Rd \approx Td \times 1/2$). Therefore, conventionally, a convex **106** is provided in the reflection region on the pixel electrode substrate **104** and the reflection pixel electrode part **101** is disposed on the convex **106** as described in Japanese Laid-Open Patent Publication No. 11-101992 (corresponding to U. S. Patent No. 6195140) and Japanese Laid-Open Patent Publication No. 2001-42332.

SUMMARY OF THE INVENTION

In the above-described conventional LCD, however, when the pixel electrode substrate **104** is subjected to the rubbing processing, a portion **S** of the pixel electrode substrate **104** shaded with the convex **106** from the rubbing processing (hereinafter simply referred to as the shade portion **S**), namely, a portion of the pixel electrode substrate **104** where orientation-regulating force to liquid crystal molecules **105a** is weak, is unavoidably caused in the transmission region **T** on a downstream side along the rubbing direction (a right hand side in FIG. **6**) of the convex **106**. Therefore, a region of a liquid crystal layer **105** corresponding to this shade portion **S** is visually identified as a domain in the transmission display mode, which disadvantageously lowers the display quality in the transmission display mode.

In order to overcome this disadvantage, the shade portion **S** may be moved from the transmission region **T** to the reflection region **R** because such a domain is more difficult to identify when formed in the reflection region **R** than when formed in the transmission region **T**. In other words, the convex **106** may be shifted toward the upstream side along the rubbing direction (namely, toward the left hand side in FIG. **6**).

The range of the reflection region **R** is, however, defined by the reflection pixel electrode part **101**, and therefore, when the convex **106** is shifted toward the upstream side

along the rubbing direction, the reflection pixel electrode part **101** is also shifted toward the upstream side along the rubbing direction. In other words, the reflection region **R** itself is shifted toward the upstream side along the rubbing direction together with the convex **106**. Accordingly, unless the convex **106** can be shifted relatively to the reflection pixel electrode part **101**, the shade portion **S** cannot be moved from the transmission region **T** to the reflection region **R** in principle.

Accordingly, as a countermeasure against the aforementioned domain, there is generally no other way than masking the domain region by using a mask layer. In this case, however, the aperture ratio of the transmission region **T** is unavoidably sacrificed accordingly to the masking as compared with design in which such masking is not employed.

The present invention was devised in consideration of the conventional disadvantage, and a principal object of the invention is, with respect to a transmission/reflection combination type LCD in which each pixel has a reflection region and a transmission region and the thickness of a liquid crystal layer is smaller in the reflection region than in the transmission region, providing an LCD that can suppress, without sacrificing the aperture ratio of the transmission region, lowering of the display quality in the transmission region derived from a domain formed because of a portion shaded from the rubbing processing with a convex provided for obtaining the different thicknesses of the liquid crystal layer.

In order to achieve the object, according to the present invention, attention is paid to that the reflection region is defined by the reflection pixel electrode part provided on the pixel electrode substrate. Therefore, the convex is provided not on the pixel electrode substrate but on the counter electrode substrate, and the convex is shifted relatively to the reflection pixel electrode part to the upstream side along the rubbing direction. Thus, the

portion shaded from the rubbing processing with the convex can be moved from the transmission region to the reflection region.

Specifically, the liquid crystal display device of this invention includes a pixel electrode substrate having a reflection pixel electrode part and a transmission pixel electrode part with respect to each pixel; a counter electrode substrate having a counter electrode part and disposed with the counter electrode part opposing the reflection pixel electrode part and the transmission pixel electrode part of the pixel electrode substrate; and a liquid crystal layer interposed between the pixel electrode substrate and the counter electrode substrate, and each pixel has a reflection region corresponding to the reflection pixel electrode part and a transmission region corresponding to the transmission pixel electrode part, and a surface of the counter electrode substrate facing the liquid crystal layer has been rubbed in a given rubbing direction.

The counter electrode substrate has a convex for making a thickness of the liquid crystal layer smaller in the reflection region than in the transmission region, and in addition, an end of the convex on a downstream side along the rubbing direction is disposed in a position shifted toward an upstream side along the rubbing direction relatively to the reflection pixel electrode part. At this point, the shift extent of the end of the convex on the downstream side along the rubbing direction relative to the reflection pixel electrode part is preferably 1 μm or more. Herein, the "shift of the convex relative to the reflection pixel electrode part" is the relative positional relationship between the reflection pixel electrode part and the convex, and therefore, a given portion of the reflection pixel electrode part may be shifted against the convex or both the reflection pixel electrode part and the convex may be shifted against each other. However, in the case where the numerical aperture of the transmission region originally designed is desired to keep, namely, in the case where the numerical aperture of the transmission region is not

sacrificed at all, a give portion of the convex is shifted against the reflection pixel electrode part literally.

In the case where the reflection pixel electrode part is formed to cross a whole region of the pixel along a direction perpendicular to the rubbing direction, the convex can be formed to cross the whole region of the pixel along the direction the same as the reflection pixel electrode part.

Furthermore, not only the end of the convex on the downstream side along the rubbing direction but also ends of the convex along a direction perpendicular to the rubbing direction may be shifted to be closer to each other relatively to the reflection pixel electrode part.

Moreover, in the case where the counter electrode substrate includes a color filter layer provided to each pixel, a transparent layer for elevating a portion of the color filter layer corresponding to the reflection region toward the reflection pixel electrode part is provided in the portion of the color filter layer corresponding to the reflection region on a side of the color filter layer not facing the liquid crystal layer, so that the convex may correspond to the portion elevated by the transparent layer.

In this case, a part of the color filter layer disposed in the reflection region may correspond to a transparent portion having higher transmissivity than the other part of the color filter layer disposed in the reflection region.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a cross-sectional view taken along line I-I of FIG. **2**.

FIG. **2** is a schematic plan view of a CF substrate (i.e., a color filter substrate working as a counter electrode substrate) of a liquid crystal display panel of an LCD according to Embodiment 1 of the invention.

FIG. **3** is a schematic plan view of a CF substrate of a liquid crystal display panel of an LCD according to Embodiment 2 of the invention.

FIG. **4** is a schematic plan view of a CF substrate of a liquid crystal display panel of an LCD according to Embodiment 3 of the invention.

FIG. **5** is a schematic plan view of a CF substrate of a liquid crystal display panel of an LCD according to a modification of Embodiment 3 of the invention.

FIG. **6** is a schematic cross-sectional view of a main part of a liquid crystal display panel of a conventional LCD.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Preferred embodiments of the invention will now be described with reference to the accompanying drawings.

EMBODIMENT 1

FIGS. **1** and **2** schematically show a main part of a liquid crystal display panel of a transmission/reflection combination type liquid crystal display device (LCD) according to Embodiment 1 of the invention, and this LCD produces displays in both a transmission display mode and a reflection display mode. FIG. **1** shows the cross-sectional structure taken along line I-I of FIG. **2**, and FIG. **2** shows the plane structure of a counter electrode substrate seen from a pixel electrode substrate.

The liquid crystal display panel of this LCD includes a TFT substrate **20** that has a reflection pixel electrode part **21** and a transmission pixel electrode part **22** with respect to each pixel; and a color filter substrate **10** (hereinafter referred to as the CF substrate) that has a counter electrode part **11** and is disposed with the counter electrode part **11** opposing the reflection pixel electrode part **21** and the transmission pixel electrode part **22** of the TFT substrate **20**. The counter electrode part **11** is provided so as to cover a plurality of

pixels, and the reflection pixel electrode part **21** is disposed at substantially the center of each pixel and the transmission pixel electrode part **22** is disposed so as to surround the reflection pixel electrode part **21**. A liquid crystal layer **40** is interposed between these substrates **10** and **20**. This liquid crystal display panel is of an ECB (Electrically Controlled Birefringence) mode in which the birefringence of the liquid crystal layer **40** is utilized and incident light is controlled to transmit/cut by changing the orientation of liquid crystal molecules **40a** in accordance with an electric field.

The TFT substrate **20** includes a transparent substrate **23** made from an insulating transparent material such as glass. On the transparent substrate **23**, a plurality of signal lines **24** and a plurality of scanning lines **25** are disposed so as to cross with each other in a matrix. A TFT (Thin Film Transistor) **26** including a source electrode **26a**, a drain electrode **26b** and a gate electrode **26c** is provided in the vicinity of each crossing between the signal line **24** and the scanning line **25**. A gate insulating film **26d** is disposed between a combination of the source electrode **26a** and the drain electrode **26b**, and the gate electrode **26c**. The source electrode **26a** is connected to the signal line **24**, and the gate electrode **26c** is connected to the scanning line **25**. Also, the drain electrode **26b** of the TFT **26** extends to substantially the center of the pixel and is covered with a protection layer **27**.

An insulating layer **28** is deposited on the signal line **24**, the scanning line **25** and the TFT **26**, and the reflection pixel electrode part **21** and the transmission pixel electrode part **22** are disposed on the insulating layer **28**. A contact hole **28a** penetrating the insulating layer **28** in the thickness direction is formed in a portion of the insulating layer **28** corresponding to substantially the center of the reflection pixel electrode part **21**, so that the reflection pixel electrode part **21** can be connected to the drain electrode **26b** of the TFT **26** through the contact hole **28a**. Also, on the face of the insulating layer **28** facing

the transparent substrate **23**, a capacitor electrode line **29** for forming additional capacitance **Cs** for storing a signal between each of the pixel electrode parts **21** and **22** and the capacitor electrode line **29** is disposed so as to extend in parallel to the scanning line **25**. The gate insulating film **26d** of the TFT **26** is provided so as to extend over the capacitor electrode line **29**.

The reflection pixel electrode part **21** is made from a metal reflection film, such as an aluminum (Al) film, having a light reflection function and an electrode function, and a region of the liquid crystal layer **40** corresponding to the reflection pixel electrode part **21** is defined as a reflection region **R** used in the reflection display mode. On the other hand, the transmission pixel electrode part **22** is made from a transparent conducting film of, for example, ITO (Indium Tin Oxide) having a light transmission function and an electrode function, and is connected, at its inner edge, to the edge of the metal reflection film working as the reflection pixel electrode part **21**. A region of the liquid crystal layer **40** corresponding to the transmission pixel electrode part **22** is defined as a transmission region **T** used in the transmission display mode. Although the metal reflection film of the reflection pixel electrode part **21** and the transparent conducting film of the transmission pixel electrode part **22** are connected to each other with their edges butted against each other in this embodiment, the metal reflection film and the transparent conducting film can be connected to each other with their edges overlapped. Alternatively, the transparent conducting film may be disposed also in the reflection region **R** with a metal reflection film deposited on the transparent conducting film in the reflection region, so that the reflection pixel electrode part **21** may be composed of a combination of the transparent conducting film disposed in the reflection region and the metal reflection film. Alternatively, with the transparent conducting film disposed also in the reflection region **R**, a reflection film at least having a light reflection function is disposed below the transparent

conducting film in the reflection region, so that the reflection pixel electrode part **21** may be composed of a combination of the transparent conducting film disposed in the reflection region and the reflection film.

An alignment layer **30** having been rubbed in a predetermined direction is provided on the reflection pixel electrode part **21** and the transmission pixel electrode part **22**, so that the liquid crystal molecules **40a** present in the vicinity of the interface between the liquid crystal layer **40** and the TFT substrate **20** can be oriented in parallel to the TFT substrate **20** and in the predetermined direction.

On the other hand, the CF substrate **10** also includes a transparent substrate **12** made from an insulating transparent material such as glass. A color filter layer **13** is provided with respect to each pixel on the face of the transparent substrate **12** facing the liquid crystal layer **40**. At this point, an opening **13a** working as a colorless portion penetrating the color filter layer **13** in the thickness direction is provided in a portion of the color filter layer **13** corresponding to substantially the center of the reflection pixel electrode part **21**. The counter electrode part **11** is provided on the color filter layer **13**. This counter electrode part **11** is made from a transparent conducting film of ITO or the like similarly to the transparent pixel electrode part **22**. An alignment layer **14** having been rubbed in a direction shown with an arrow in each of FIGS. **1** and **2** is provided on the counter electrode part **11**, so that the liquid crystal molecules **40a** present in the vicinity of the interface between the liquid crystal layer **40** and the CF substrate **10** can be oriented in parallel to the CF substrate **10** and in the direction shown with the arrow.

In this embodiment, the CF substrate **10** has a convex **15** for making the thickness **Rd** of the liquid crystal layer **40** in the reflection region **R** smaller than the thickness **Td** of the liquid crystal layer **40** in the transmission region **T** (Rd < Td).

Specifically, between a portion of the color filter layer **13** and a portion of the

counter electrode part **11** both corresponding to the reflection region **R**, a transparent layer **16** is provided so as to elevate the portion of the counter electrode part **11** corresponding to the reflection region **R** toward the reflection pixel electrode part **21** provided on the TFT substrate **20**, and the convex **15** corresponds to the portion elevated by this transparent layer **16**. Also, the opening **13a** of the color filter layer **13** is filled with a part of the transparent layer **16**. Such a transparent layer **16** is formed, for example, as follows: A film made from a negative transparent acrylic resin-based photosensitive material is formed on the transparent substrate **12**, the photosensitive material is patterned into a desired shape through exposure to activation light, the resultant is developed with an alkaline developer and cleaned with water so as to remove an unexposed portion of the film, and annealing is ultimately performed. Alternatively, the transparent layer can be formed through patterning by etching, printing, transferring or the like.

In addition, in this embodiment, the end of the convex **15** on the downstream side along the rubbing direction (namely, the right end in FIG. **1**; hereinafter referred to as the downstream end) is disposed in a position shifted to the upstream side along the rubbing direction (namely, to the left hand side in FIG. **1**) from the boundary between the transmission region **T** and the reflection region **R** shown with a virtual line as shown in FIG. **1**. (It is noted that words "downstream" and "upstream" herein mean directions along the rubbing direction.) Therefore, a shade portion **S** shaded from the rubbing processing with the convex **15**, that is, a portion in the vicinity of and on the downstream side of the convex **15**, is positioned on the side of the reflection region **R** (on the left hand side in FIG. **1**).

More specifically, since the convex **15** is provided not on the TFT substrate **20** but on the CF substrate **10**, the convex **15** can be shifted relatively to the reflection region **R** defined by the reflection pixel electrode part **21** disposed on the TFT substrate **20**. Since

the downstream end of the convex **15** is shifted to the upstream side relatively to the reflection pixel electrode part **21**, at least a part of the shade portion **S**, namely, the portion in the vicinity of and on the downstream side of the convex **15**, is moved from the transmission region **T** to the reflection region **R**. Therefore, at least a part of a domain formed in a region of the liquid crystal layer **40** correspondingly to and because of the shade portion **S** is accordingly moved from the transmission region **T** to the reflection region **R**, and hence, the lowering of display quality in the transmission region **T** derived from such a domain can be suppressed accordingly to the shift, and in addition, the numerical aperture of the transmission region **T** is never sacrificed.

Furthermore, in this embodiment, in addition to the downstream end of the convex **15**, both ends (the right and left ends in FIG. **2**) of the convex **15** along a direction perpendicular to the rubbing direction are shifted to be closer each other (i.e., in the lateral direction in FIG. **2**) relatively to the reflection pixel electrode part **21**, and hence, portions in the vicinity of and on the both sides of the convex **15** that are difficult to sufficiently rub can be positioned on the side of the reflection region **R**. It is noted that the end of the convex **15** on the upstream side is disposed in the same position along the rubbing direction as the corresponding end of the reflection pixel electrode part **21** in this embodiment in the same manner as in the conventional technique.

Specifically, the transparent layer **16** is formed to have a rectangular plane shape smaller than that of the reflection pixel electrode part **21**, and thus, the ends of the convex **15** can be shifted toward the reflection region **R**. The shift extent **M** of each end of the convex **15** is at least 1 μm or more ($M \geq 1$ μm) and preferably 2 μm or more ($M \geq 2$ μm). In other words, in the case where the respective thicknesses **Rd** and **Td** of the liquid crystal layer **40** in the reflection region **R** and the transmission region **T** have general values, the dimension of the domain formed because of the shade portion **S** from the downstream end

of the convex (i.e., the rubbing direction dimension of the domain) largely depends upon the height of the convex **15** and is regarded to be varied also in accordance with various factors such as the liquid crystal material, the alignment layer and rubbing conditions. However, it has been found through an experiment as described below that the rubbing direction dimension of the domain is not within 1 μm. Therefore, when the shift extent **M** of the downstream end of the convex **15** relatively to the reflection pixel electrode part **21** is 1 μm or more ($M \geq 1$ μm), at least a part of the domain formed because of the shade portion **S** of the convex **15** can be moved from the transmission region **T** to the reflection region **R**.

Thus, according to this embodiment, in the transmission/reflection combination type LCD in which each pixel includes the reflection region **R** and the transmission region **T** and the liquid crystal layer **40** has the thickness **Rd** in the reflection region **R** smaller than the thickness **Td** in the transmission region **T**, the convex **15** formed on the CF substrate **10** for making the thicknesses **Rd** and **Td** different from each other is provided so as to have its downstream end in the position shifted toward the upstream side relatively to the reflection pixel electrode part **21** disposed on the TFT substrate **20**. Therefore, at least a part of the domain formed in the region of the liquid crystal layer **40** correspondingly to and because of the shade portion **S** formed on the downstream side of the convex **15** can be moved from the transmission region **T** where such a domain is easily seen to the reflection region **R** where it is difficult to see. As a result, without scarifying the numerical aperture of the transmission region **T**, the lowering of the display quality derived from such a domain can be suppressed.

Furthermore, in addition to the downstream end of the convex **15**, the ends of the convex **15** along the direction perpendicular to the rubbing direction are shifted to be closer to each other relatively to the reflection pixel electrode part **21**. Therefore, also domains

formed in regions of the liquid crystal layer **40** correspondingly to and because of shade portions S formed in the vicinity of and on the both sides of the convex **15** that are difficult to sufficiently rub can be also moved from the transmission region **T** to the reflection region **R**. Accordingly, the lowering of the display quality also derived from such domains can be suppressed without sacrificing the numerical aperture of the transmission region **T**.

Moreover, the convex **15** is formed by providing the transparent layer **16** between the transparent substrate **12** and the color filter layer **13**. Therefore, the convex **15** can be formed without increasing the thickness of the color filter layer **13**, and hence, lowering of the transmissivity in the reflection region **R** derived from a large thickness of the color filter layer **13** can be avoided.

Furthermore, the opening **13a** is formed in a part of the color filter layer **13** in the reflection region **R** and the material for the transparent layer **16** is filled in the opening **13a**. Therefore, this opening **13a** can be a transparent portion with higher transmissivity than the other portion of the color filter layer **13**, which can rather increase the transmissivity in the reflection region **R**. In addition, the function of the color filter layer **13** is not largely spoiled.

Although the reflection pixel electrode part **21** is disposed in the same position along the thickness direction as the transmission pixel electrode part **22** so as to make flat the face of the TFT substrate **20** facing the liquid crystal layer **40** in this embodiment, the present invention does not exclude the reflection pixel electrode part **21** formed in a projecting shape as in the conventional technique. However, in the case where the reflection pixel electrode part **21** is formed in a projecting shape, the size and the shape of the projecting portion should be designed so that the TFT substrate **20** can be sufficiently rubbed.

Also, the transmission display mode and the reflection display mode are both employed for producing a display by electrically connecting the reflection pixel electrode part **21** and the transmission pixel electrode part **22** to each other in this embodiment. However, without connecting the reflection pixel electrode part **21** and the transmission pixel electrode part **22** to each other, a signal from the signal line **24** can be alternatively supplied to either the reflection pixel electrode part **21** or the transmission pixel electrode part **22** for producing a display in a mode switched between the transmission display mode and the reflection display mode.

Furthermore, although the LCD for producing a color display is described in this embodiment, the present invention is applicable to an LCD for producing a monochrome display.

- Experiment –

Now, an experiment performed for examining the relationship between the thickness **Wd** of the transparent layer **16** (namely, the height of the convex **15**) and the dimension along the rubbing direction of the domain formed because of the shade portion **S** of the convex **15** will be described.

Specifically, three liquid crystal display panel models of Experiment Examples 1 through 3 in which the thicknesses of the transparent layers **16** are different in accordance with the thicknesses **Rd** and **Td** of the liquid crystal layers **40** in the reflection region **R** and the transmission region **T** are fabricated, and the rubbing direction dimension of the domain is measured in each example.

In Experiment Example 1, the thicknesses **Rd** and **Td** of the liquid crystal layer **40** in the reflection region **R** and the transmission region **T** are set to 2.5 μm and 5.0 μm, respectively, and therefore, the thickness **Wd** of the transparent layer **16** is set to 2.5 μm.

In Experiment Example 2, the thicknesses **Rd** and **Td** of the liquid crystal layer

40 in the reflection region R and the transmission region T are set to 3.0 μm and 4.0 μm, respectively, and therefore, the thickness Wd of the transparent layer 16 is set to 1.0 μm.

In Experiment Example 3, the thicknesses Rd and Td of the liquid crystal layer 40 in the reflection region R and the transmission region T are set to 2.0 μm and 5.5 μm, respectively, and therefore, the thickness Wd of the transparent layer 16 is set to 3.5 μm.

The conditions and the results of the experiment are both listed in the following table:

	Experiment Example 1	Experiment Example 2	Experiment Example 3
Td in region T	5.0 μm	4.0 μm	5.5 μm
Rd in region R	2.5 μm	3.0 μm	2.0 μm
Wd of transparent layer	2.5 μm	1.0 μm	3.5 μm
Dimension of domain	2.0 μm	1.0 μm	3.0 μm

As is understood from the table, the rubbing direction dimension of the domains obtained in Experiment Examples 1 through 3 are 2.0 μm, 1.0 μm and 3.0 μm, respectively. Accordingly, it is understood that the shift extent M of the convex 15 should be 1 μm or more ($M \geq 1$ μm).

In Experiment Example 1, it is assumed that the domain is masked by using a mask layer having an area corresponding to the area of the shade portion S of convex 15 instead of moving the domain completely to the reflection region R by shifting the downstream end of the convex 15 toward the upstream side by 2 μm. Under this assumption, a loss ratio of the numerical aperture Pa of the transmission region T obtained in using the mask layer to the numerical aperture Pb originally obtained without using the mask layer, [(Pb – Pa)/Pb], is calculated. When the original numerical aperture obtained without using the mask layer is approximately 60%, the loss ratio is approximately 1.5%. In suppressing the lowering of the display quality in the transmission region T derived from the domain, the means of this invention of shifting the downstream end of the convex 15 toward the upstream side is more remarkably effective as the original numerical

aperture **Pb** of the transmission region **T** is designed to be lower because the area of the shade portion **S** of the convex **15** is substantially constant.

EMBODIMENT 2

FIG. **3** shows the plane structure of a main part of a CF substrate **10** used in a liquid crystal display panel of an LCD according to Embodiment 2 of the invention. In FIG. **3**, like reference numerals are used to refer to like elements used in Embodiment 1.

In this embodiment, the downstream end of the convex **15** (namely, the upper end in FIG. **3**) alone is shifted but both ends of the convex **15** along the direction perpendicular to the rubbing direction (namely, the right and left ends in FIG. **3**) are not shifted but disposed in positions substantially overlapping the corresponding ends of the reflection pixel electrode part **21** as in the conventional technique. Apart from this, the structure of this LCD is the same as that of Embodiment 1, and hence the description is herein omitted.

Accordingly, this embodiment can exhibit the same effect as that of Embodiment 1 except that the lowering of the display quality derived from the domains formed in the regions of the liquid crystal layer **40** correspondingly to and because of the portions in the vicinity of and on both the sides of the convex **15** that are difficult to sufficiently rub cannot be suppressed.

EMBODIMENT 3

FIG. **4** shows the plane structure of a main part of a CF substrate **10** used in a liquid crystal display panel of an LCD according to Embodiment 3 of the invention. In FIG. **4**, like reference numerals are used to refer to like elements used in Embodiment 1.

In this embodiment, not only the downstream end of the convex **15** (namely, the upper end in FIG. **4**) but also the end of the convex **15** on the upstream side (namely, the lower end in FIG. **4**) is shifted toward the upstream side relatively to the reflection pixel electrode part **21**, and the shift extent of the latter end is the same as that of the former end.

Also, both ends of the convex **15** along the direction perpendicular to the rubbing direction (namely, the right and left ends in FIG. **4**) are disposed in positions substantially overlapping the corresponding ends of the reflection pixel electrode part **21** as in Embodiment 2.

In other words, the plane shape and the size of the transparent layer **16** used for forming the convex **15** are substantially the same as those of the reflection pixel electrode part **21**, and the convex **15** in such shape and size is shifted as a whole. In this case, the end of the convex **15** on the upstream side is present in the transmission region **T**, and hence, the thickness of the liquid crystal layer **40** in the transmission region **T** is changed. Therefore, although a region having a rather different electro-optical characteristic is formed, this region does not lead to a problem in the visibility. Accordingly, there is no need to mask the region with a mask layer, and hence, the numerical aperture of the transmission region **T** is not sacrificed. Apart from this, the structure of the LCD of this embodiment is the same as that of Embodiment 1 and hence the description is herein omitted.

Accordingly, also this embodiment can exhibit the effect the same as that of Embodiment 2. In addition, the shape and the size of the transparent layer **16** can be easily set at the step of panel design, and the alignment of the CF substrate **10** and the TFT substrate **20** can be eased at a panel alignment step for placing the substrate**10** on the substrate **20**.

A modification of this embodiment is shown in FIG. **5**, which is a plan view of a main part on a CF substrate **10**. As shown in FIG. **5**, a reflection pixel electrode part **21** disposed on a TFT substrate **20** is formed so as to extend over the whole region of each pixel along the direction parallel to a scanning line **25**, and convexes **15**, namely, transparent layers **16**, disposed on the CF substrate **10** are formed in the shape of

continuous stripes crossing the whole region of each pixel along the direction parallel to the scanning line **25** over a plurality of pixels arranged along the direction of the scanning line **25**. In this case, the whole convex **15** can be formed to be shifted toward the upstream side relatively to the reflection pixel electrode part **21** of each pixel. Therefore, in positioning the convex **15** relatively to the reflection pixel electrode part **21** at the panel alignment step, there is no need to control the position along the direction perpendicular to the rubbing direction, and hence, the positioning work can be eased. It is noted that the position along the rubbing direction should be still controlled.